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(54) Title: **METHODS AND COMPOSITIONS FOR MODULATING ALPHA ADRENERGIC RECEPTOR ACTIVITY**

(57) Abstract: Methods and compositions for the treatment of pain. Particularly disclosed are new compositions for the treatment of chronic pain, and methods for their use.

WO 01/78702 A2

METHODS AND COMPOSITIONS FOR MODULATING ALPHA
ADRENERGIC RECEPTOR ACTIVITY

5

This application is a continuation-in-part of co-pending serial number 09/548,315, filed April 13, 2000.

10

BACKGROUND OF THE INVENTION

Human adrenergic receptors are integral membrane proteins which have been classified into two broad classes, the alpha and the beta adrenergic receptors. Both types mediate the action of the peripheral sympathetic nervous system upon binding of catecholamines, norepinephrine and epinephrine.

Norepinephrine is produced by adrenergic nerve endings, while epinephrine is produced by the adrenal medulla. The binding affinity of adrenergic receptors for these compounds forms one basis of the classification: alpha receptors tend to bind norepinephrine more strongly than epinephrine and much more strongly than the synthetic compound isoproterenol. The preferred binding affinity of these hormones is reversed for the beta receptors. In many tissues, the functional responses, such as smooth muscle contraction, induced by alpha receptor activation are opposed to responses induced by beta receptor binding.

Subsequently, the functional distinction between alpha and beta receptors was further highlighted and refined by the pharmacological characterization of these receptors from various animal and tissue

sources. As a result, alpha and beta adrenergic receptors were further subdivided into α_1 , α_2 , β_1 , and β_2 subtypes.

Functional differences between α_1 and α_2 receptors have been recognized, and compounds which exhibit selective binding between these two subtypes have been developed. Thus, in WO 92/0073, the selective ability of the R(+) enantiomer of terazosin to selectively bind to adrenergic receptors of the α_1 subtype was reported. The α_1/α_2 selectivity of this compound was disclosed as being significant because agonist stimulation of the α_2 receptors was said to inhibit secretion of epinephrine and norepinephrine, while antagonism of the α_2 receptor was said to increase secretion of these hormones. Thus, the use of non-selective alpha-adrenergic blockers, such as phenoxybenzamine and phentolamine, was said to be limited by their α_2 adrenergic receptor mediated induction of increased plasma catecholamine concentration and the attendant physiological sequelae (increased heart rate and smooth muscle contraction).

For a general background on the α -adrenergic receptors, the reader's attention is directed to Robert R. Ruffolo, Jr., α -Adrenoreceptors: Molecular Biology, Biochemistry and Pharmacology, (Progress in Basic and Clinical Pharmacology series, Karger, 1991), wherein the basis of α_1/α_2 subclassification, the molecular biology, signal transduction, agonist structure-activity relationships, receptor functions, and therapeutic applications for compounds exhibiting α -adrenergic receptor affinity was explored.

The cloning, sequencing and expression of alpha receptor subtypes from animal tissues has led to the subclassification of the α_1 adrenoreceptors into α_{1A} , α_{1B} , and α_{1D} . Similarly, the α_2 adrenoreceptors have
5 also been classified α_{2A} , α_{2B} , and α_{2C} receptors. Each α_2 receptor subtype appears to exhibit its own pharmacological and tissue specificities. Compounds having a degree of specificity for one or more of these subtypes may be more specific therapeutic
10 agents for a given indication than an α_2 receptor pan-agonist (such as the drug clonidine) or a pan-antagonist.

Among other indications, such as the treatment of glaucoma, hypertension, sexual dysfunction, and
15 depression, certain compounds having alpha 2 adrenergic receptor agonist activity are known analgesics. However, many compounds having such activity do not provide the activity and specificity desirable when treating disorders modulated by alpha-
20 2 adrenoreceptors. For example, many compounds found to be effective agents in the treatment of pain are frequently found to have undesirable side effects, such as causing hypotension and sedation at systemically effective doses. There is a need for new
25 drugs that provide relief from pain without causing these undesirable side effects. Additionally, there is a need for agents which display activity against pain, particularly chronic pain, such as chronic neuropathic and visceral pain.

30 British Patent 1 499 485, published February 1, 1978 describes certain thiocarbamide derivatives; some of these are said to be useful in the treatment

of conditions such as hypertension, depression or pain.

OBJECTS OF THE INVENTION

5

It is an object of the invention to provide compounds and compositions useful in treating disorders modulated by alpha-2 adrenoreceptors.

10 It is an object of this invention to provide novel compounds having substantial analgesic activity in the treatment of chronic pain, regardless of origin. Chronic pain may be, without limitation, visceral, inflammatory, referred or neuropathic in origin. Such chronic pain may arise as a result of,
15 or be attendant to, conditions including without limitation: arthritis, (including rheumatoid arthritis), spondylitis, gouty arthritis, osteoarthritis, juvenile arthritis, and autoimmune diseases including, without limitation, lupus
20 erythematosus.

These compositions can also be used within the context of the treatment of chronic gastrointestinal inflammations, Crohn's disease, gastritis, irritable
25 bowel disease (IBD) and ulcerative colitis; and in treatment of visceral pain, including pain caused by cancer or attendant to the treatment of cancer as, for example, by chemotherapy or radiation therapy.

These compositions can be used within the context of the treatment of other chronic pain
30 symptoms, and especially in the treatment of chronic forms of neuropathic pain, in particular, without limitation, neuralgia, herpes, deafferentation pain, and diabetic neuropathies. In a preferred embodiment these compositions are specifically analgesic in

chronic pain models and do not have significant activity in acute pain models.

It is also an object of this invention to provide novel compounds for treating ocular disorders, such as ocular hypertension, glaucoma, hyperemia, conjunctivitis and uveitis.

It is also an object of this invention to provide novel compounds for treating the pain associated with substance abuse and/or withdrawal.

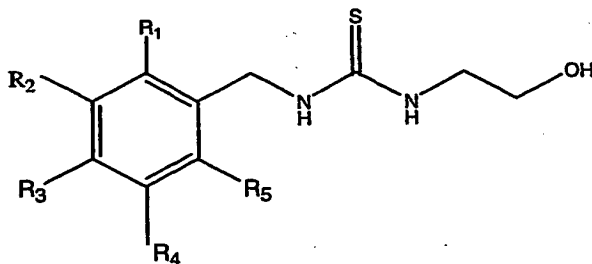
It is a still further object of this invention to provide such compounds which have good activity when delivered by peroral, parenteral, intranasal, ophthalmic, and/or topical dosing, or injection.

It is also an object of this invention to provide methods of treating pain through the therapeutic administration of the compounds disclosed herein.

It is further an object of the present invention to provide methods of treating conditions known to be susceptible to treatment through alpha 2 adrenergic receptors.

SUMMARY OF THE INVENTION

The present invention is directed to compounds having the formula:



wherein R_1 and R_5 are independently selected from the group consisting of Cl, F, I, Br, C_{1-3} alkyl, C_{1-3} alkoxy, trifluoromethyl, hydroxyl or H, R_2 and R_4 are independently selected from the group consisting of Cl, F, I, Br, C_{1-3} alkyl, C_{1-3} alkoxy, hydroxyl, trifluoromethyl or H, and R_3 is selected from the group consisting of F or H; and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

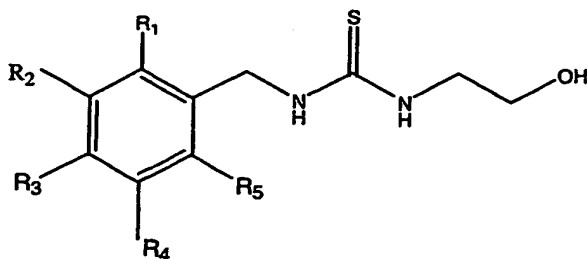
The invention is also directed to methods of treating pain, particularly chronic pain, through the administration of pharmaceutically effective amounts of compounds of the above structure.

In an alternative embodiment, the invention is directed to compounds of the structure of Formula 1, excepting the compound(s) designated below as Formula 2 and/or Formula 3.

Further, the invention is directed to methods of treating glaucoma and other ophthalmic conditions (including ocular pain) through the administration of a pharmaceutically effective amount of these compounds.

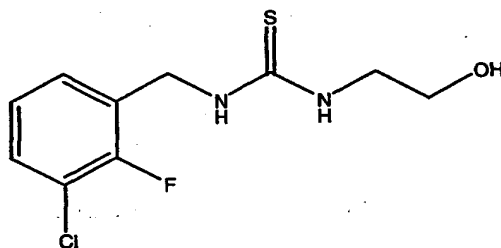
DETAILED DESCRIPTION OF THE INVENTION

In one aspect, the present invention is directed to compounds having the formula:



wherein R_1 and R_5 are independently selected from the group consisting of Cl, F, I, Br, C_{1-3} alkyl, C_{1-3} alkoxy, trifluoromethyl, hydroxyl or H, R_2 and R_4 are independently selected from the group consisting of Cl, F, I, Br, C_{1-3} alkyl, C_{1-3} alkoxy, hydroxyl, trifluoromethyl or H, and R_3 is selected from the group consisting of F or H; and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

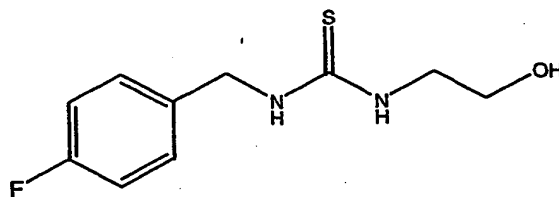
10 In one embodiment preferred compounds corresponding to this structure are the following compound (hereinafter termed Formula 2):



15

Formula 2

and the following compound (hereinafter termed Formula 3):



20

Formula 3

and their alkyl esters, and pharmaceutically acceptable derivatives and/or salts of these compounds. In an alternative embodiment, the invention is drawn to the subset of Formula 1 that

25

excludes the compounds designated Formula 2 and/or Formula 3.

Applicants have discovered that these compounds activate α_2 receptors, particularly α_{2B} receptors.

5 Additionally, these compounds act as a highly effective analgesic, particularly in chronic pain models, with minimal undesirable side effects, such as sedation and cardiovascular depression, commonly seen with agonists of the α_2 receptors.

10 Such compounds may be administered at pharmaceutically effective dosages. Such dosages are normally the minimum dose necessary to achieve the desired therapeutic effect; in the treatment of chronic pain, this amount would be roughly that
15 necessary to reduce the discomfort caused by the pain to tolerable levels. Generally, such doses will be in the range 1-1000 mg/day; more preferably in the range 10 to 500 mg/day. However, the actual amount of the compound to be administered in any given case will be
20 determined by a physician taking into account the relevant circumstances, such as the severity of the pain, the age and weight of the patient, the patient's general physical condition, the cause of the pain, and the route of administration.

25 The compounds are useful in the treatment of pain in a mammal; particularly a human being. Preferably, the patient will be given the compound orally in any acceptable form, such as a tablet, liquid, capsule, powder and the like. However, other
30 routes may be desirable or necessary, particularly if the patient suffers from nausea. Such other routes may include, without exception, transdermal, parenteral, subcutaneous, intranasal, intrathecal,

intramuscular, intravenous, and intrarectal modes of delivery. Additionally, the formulations may be designed to delay release of the active compound over a given period of time, or to carefully control the amount of drug released at a given time during the course of therapy.

Another aspect of the invention is drawn to therapeutic compositions comprising the compounds of Formula 1 and alkyl esters and pharmaceutically acceptable derivatives and/or salts of these compounds and a pharmaceutically acceptable excipient, or the subset of these compounds excluding Formula 2 and/or Formula 3. Such an excipient may be a carrier or a diluent; this is usually mixed with the active compound, or permitted to dilute or enclose the active compound. If a diluent, the carrier may be solid, semi-solid, or liquid material that acts as a excipient or vehicle for the active compound. The formulations may also include wetting agents, emulsifying agents, preserving agents, sweetening agents, and/or flavoring agents. If used as in an ophthalmic or infusion format, the formulation will usually contain one or more salt to influence the osmotic pressure of the formulation.

In another aspect, the invention is directed to methods for the treatment of pain, particularly chronic pain, through the administration of a compound of Formula 1 having activity against chronic pain, and pharmaceutically acceptable alkyl esters, salts, and derivatives thereof to a mammal in need thereof. In a preferred embodiment the compounds lack significant activity towards acute pain. In a further embodiment, such methods employ a compound selected from this group, but such compound is not

Formula 2 or Formula 3. As indicated above, the compound will usually be formulated in a form consistent with the desired mode of delivery.

It is known that chronic pain (such as pain from cancer, arthritis, and many neuropathic injuries) and acute pain (such as that pain produced by an immediate mechanical stimulus, such as tissue section, pinch, prick, or crush) are distinct neurological phenomena mediated to a large degree either by different nerve fibers and neuroreceptors or by a rearrangement or alteration of the function of these nerves upon chronic stimulation. Sensation of acute pain is transmitted quite quickly, primarily by afferent nerve fibers termed C fibers, which normally have a high threshold for mechanical, thermal, and chemical stimulation. While the mechanisms of chronic pain are not completely understood, acute tissue injury can give rise within minutes or hours after the initial stimulation to secondary symptoms, including a regional reduction in the magnitude of the stimulus necessary to elicit a pain response. This phenomenon, which typically occurs in a region emanating from (but larger than) the site of the original stimulus, is termed hyperalgesia. The secondary response can give rise to profoundly enhanced sensitivity to mechanical or thermal stimulus.

The A afferent fibers ($A\beta$ and $A\delta$ fibers) can be stimulated at a lower threshold than C fibers, and appear to be involved in the sensation of chronic pain. For example, under normal conditions, low threshold stimulation of these fibers (such as a light brush or tickling) is not painful. However,

under certain conditions such as those following nerve injury or in the herpesvirus-mediated condition known as shingles the application of even such a light touch or the brush of clothing can be
5 very painful. This condition is termed allodynia and appears to be mediated at least in part by A β afferent nerves. C fibers may also be involved in the sensation of chronic pain, but if so it appears clear that persistent firing of the neurons over time
10 brings about some sort of change which now results in the sensation of chronic pain.

By "acute pain" is meant immediate, usually high threshold, pain brought about by injury such as a cut, crush, burn, or by chemical stimulation such as
15 that experienced upon exposure to capsaicin, the active ingredient in chili peppers.

By "chronic pain" is meant pain other than acute pain, such as, without limitation, neuropathic pain, visceral pain (including that brought about by Cron's
20 disease and irritable bowel syndrome (IBS)), and referred pain.

It has been discovered that compounds of Formula 1 have activity against chronic pain. Preferably, though not necessarily, this activity is relatively
25 specific to chronic pain and the compounds have little activity towards acute pain. In one embodiment compounds of Figure 1 which are monosubstituted will have either a fluorine or hydrogen substitution at the para position.

30 Table 1 below lists exemplary thiourea compounds and indicates, with some exceptions, their ability to modulate alpha 2_A, alpha 2_B and alpha 2_C adrenergic receptor activity, indicated by the EC₅₀ value (the

concentration of the compound, expressed as 10^{-9} moles per liter, effective to cause a modulation of receptor activity). The compounds of this invention are preferably at least 10-fold less active at the
5 alpha 2_A receptor than at the alpha 2_B and/or alpha 2_C receptors. While not wishing to be limited by theory, the present inventors believe that stimulation of the alpha 2_A receptor is associated in mammals, including human beings, with cardiovascular
10 effects, sedation, and diuretic activity, which activities are preferably not desired to be stimulated in compounds to be used as drugs for the treatment of chronic pain.

Activity was measured using the RSAT (Receptor
15 Selection and Amplification Technology) assay, developed by Receptor Technologies, Inc. of Winooski, VT (now Acadia Pharmaceuticals of San Diego, CA), adapted for use with recombinant alpha2 adrenergic receptors in collaboration with Allergan. The assay
20 measures receptor-mediated loss of contact inhibition that results in selective proliferation of receptor-containing cells in a mixed population of confluent cells. The increase in cell number is assessed with an appropriate transfected marker gene such as β -
25 galactosidase, the activity of which can be easily measured in a 96-well format. Receptors that activate the G protein, G_q, elicit this response. Alpha2 receptors, which normally couple to G_i, activate the RSAT response when coexpressed with a
30 hybrid G_q protein that has a G_i receptor recognition domain, called G_{q/i5}.

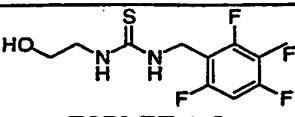
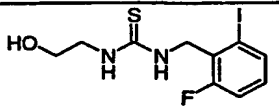
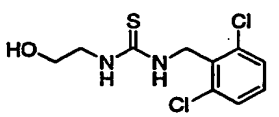
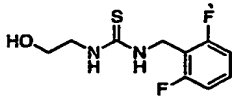
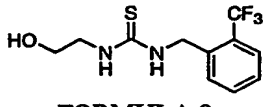
The assay is conducted as follows. NIH-3T3 cells are plated at a density of 2×10^6 cells in 15 cm

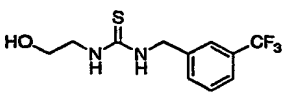
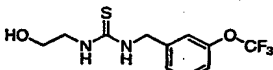
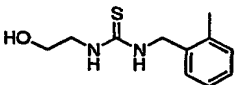
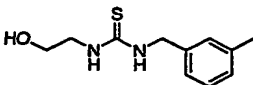
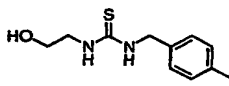
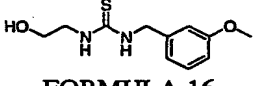
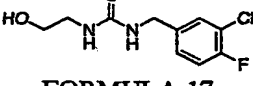
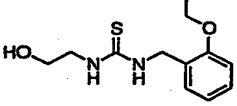
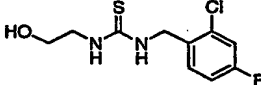
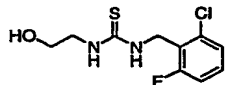
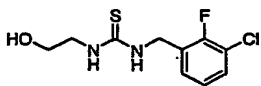
dishes and maintained in Dulbecco's modified Eagle's medium supplemented with 10% calf serum. One day later, cells are cotransfected by calcium phosphate precipitation with mammalian expression plasmids encoding p-SV- β -galactosidase (5-10 μ g), receptor (1-2 μ g) and G protein (1-2 μ g). 40 μ g salmon sperm DNA may also be included in the transfection mixture to increase transfection efficiency. Fresh media is added on the following day and 1-2 days later, cells are harvested and frozen in 50 assay aliquots. Transfectant cells are thawed and 100 μ l added to 100 μ l aliquots of various concentrations of drugs in triplicate in 96-well dishes. Incubations continue 72-96 hr at 37 $^{\circ}$. After washing with phosphate-buffered saline, β -galactosidase enzyme activity is determined by adding 200 μ l of the chromogenic substrate (consisting of 3.5 mM o-nitrophenyl- β -D-galactopyranoside and 0.5% of the non-ionic surfactant nonidet P-40 in phosphate buffered saline), incubating overnight at 30 $^{\circ}$ and measuring optical density at 420 nm. The absorbency is a measure of enzyme activity, which depends on cell number and reflects a receptor-mediated cell proliferation. The EC₅₀ and maximal effect of each drug at each α_2 receptor is determined. The efficacy or intrinsic activity is calculated as a ratio of the maximal effect of the drug to the maximal effect of a standard full agonist for each receptor subtype. Brimonidine, also called UK14304, is used as the standard agonist for the α_{2A} , α_{2B} and α_{2C} receptors. The RSAT assay is also discussed in Messier et al. (1995) *High throughput assays of cloned adrenergic, muscarinic, neurokinin*

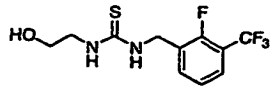
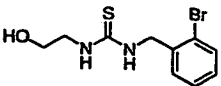
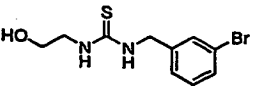
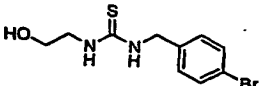
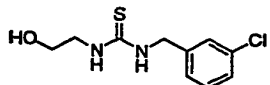
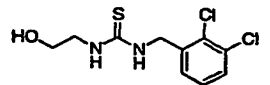
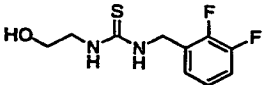
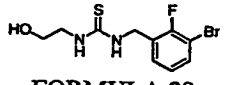
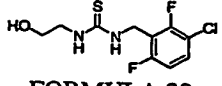
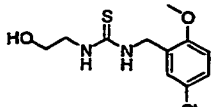
and neurotrophin receptors in living mammalian cells, Pharmacol. Toxicol. 76:308-11; see also Conklin et al. (1993) Substitution of three amino acids switches receptor specificity of $G_{q\alpha}$ to that of $G_{i\alpha}$, Nature 363:274-6; Both of these papers are incorporated by reference herein.

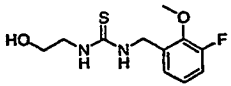
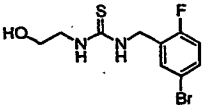
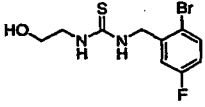
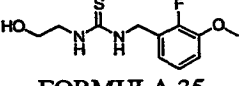
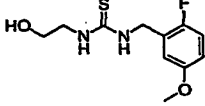
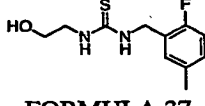
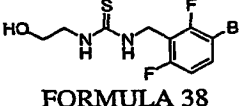
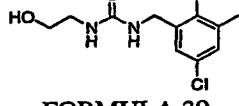
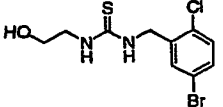
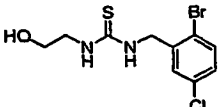
Table 1

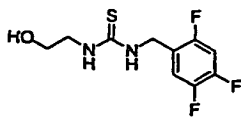
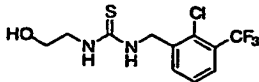
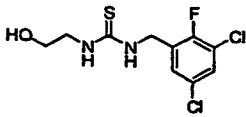
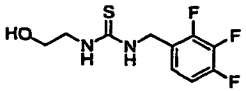
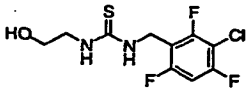
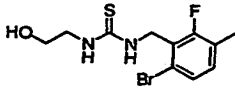
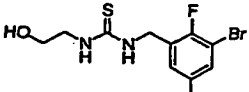
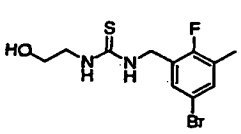
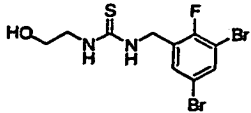
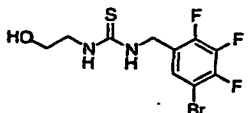
NA=Not active ($EC_{50} \geq 210,000$)
ND=Not tested

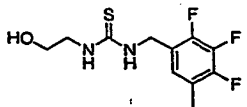
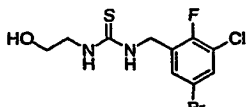
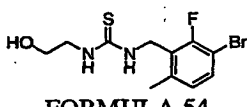
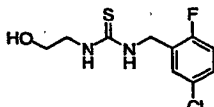
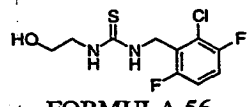
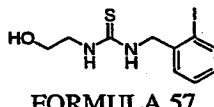
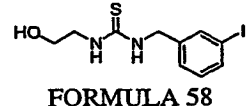
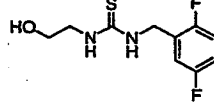
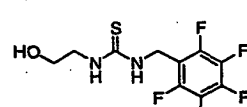
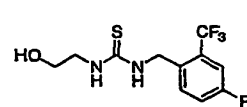
Compounds	RSAT EC_{50} (nM)		
	Alpha 2A	Alpha 2B	Alpha 2C
 FORMULA 5	NA	2053 (0.89)	NA
 FORMULA 6	NA	141 (1.08)	>2000
 FORMULA 7	NA	380 (0.93)	NA
 FORMULA 8	NA	462 (0.45)	5057 (0.4)
 FORMULA 9	NA	694 (0.93)	783 (0.4)

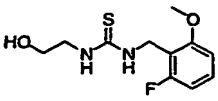
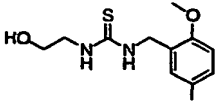
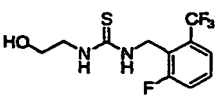
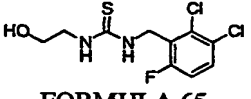
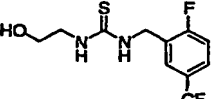
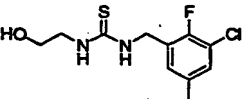
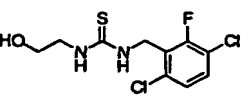
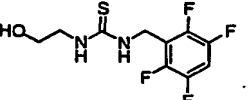
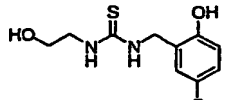
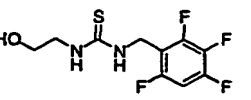
 FORMULA 10	NA	495 (0.73)	NA
 FORMULA 11	NA	2395 (0.55)	NA
 FORMULA 12	NA	174 (0.7)	NA
 FORMULA 13	NA	913 (0.9)	602 (0.3)
 FORMULA 15	NA	59 (0.6)	1805 (0.4)
 FORMULA 16	NA	898 (0.40)	NA
 FORMULA 17	NA	99 (0.6)	NA
 FORMULA 18	NA	42 (0.7)	28 (0.4)
 FORMULA 19	NA	579 (0.75)	NA
 FORMULA 20	NA	174 (0.55)	NA
 FORMULA 21	NA	16 (0.82)	457 (0.37)

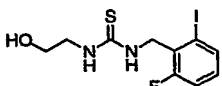
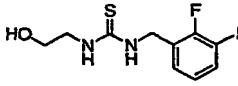
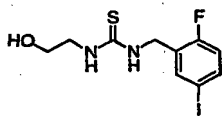
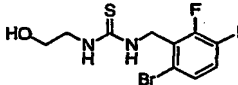
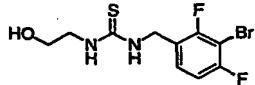
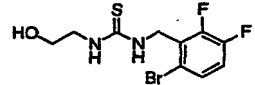
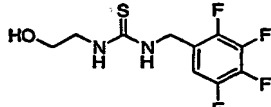
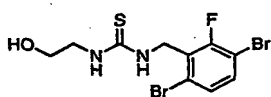
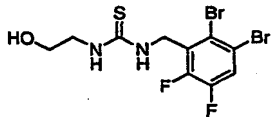
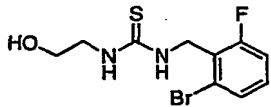
 FORMULA 22	NA	37 (0.7)	632 (0.3)
 FORMULA 23	NA	10 (0.8)	273 (0.4)
 FORMULA 24	295 (0.3)	14 (0.9)	NA
 FORMULA 25	ND	ND	ND
 FORMULA 26	NA	16 (0.7)	NA
 FORMULA 27	NA	3 (0.99)	54.5 (0.33)
 FORMULA 28	ND	ND	ND
 FORMULA 29	135.5 (0.52)	5.5 (1.03)	41 (0.88)
 FORMULA 30	NA	98 (0.83)	>2000
 FORMULA 31	379.5 (0.33)	19 (1.09)	175 (0.53)

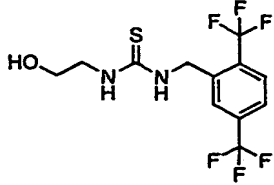
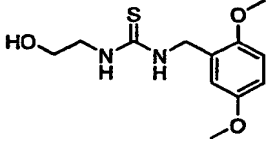
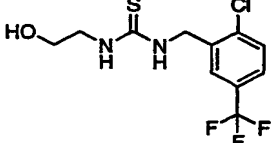
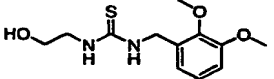
 FORMULA 32	NA	169.5 (0.95)	843 (0.38)
 FORMULA 33	NA	36 (0.97)	459 (0.58)
 FORMULA 34	NA	20 (1.0)	137 (0.63)
 FORMULA 35	>2000	429 (1.04)	>3000
 FORMULA 36	NA	282 (0.91)	ND
 FORMULA 37	NA	95 (0.91)	ND
 FORMULA 38	NA	205 (0.81)	ND
 FORMULA 39	NA	37.5 (1.02)	181 (0.62)
 FORMULA 40	NA	50 (0.78)	ND
 FORMULA 41	NA	25 (0.82)	ND

 FORMULA 42	NA	271 (0.48)	ND
 FORMULA 43	NA	33 (1.1)	ND
 FORMULA 44	NA	118 (0.92)	ND
 FORMULA 45	NA	482 (0.76)	NA
 FORMULA 46	NA	281 (0.58)	NA
 FORMULA 47	NA	115 (0.8)	>3000
 FORMULA 48	>2000	22 (0.73)	819 (0.56)
 FORMULA 49	NA	240 (0.8)	1486 (0.37)
 FORMULA 50	NA	116 (1.23)	1408 (0.58)
 FORMULA 51	NA	512 (1.07)	NA

 FORMULA 52	NA	120 (0.92)	NA
 FORMULA 53	NA	117 (1.13)	>2000
 FORMULA 54	NA	181 (0.95)	>2000
 FORMULA 55	NA	17 (1.13)	87 (0.6)
 FORMULA 56	NA	44 (0.94)	1852 (0.54)
 FORMULA 57	NA	21 (1.26)	226 (0.7)
 FORMULA 58	63 (0.42)	30 (1.16)	232 (0.58)
 FORMULA 59	NA	13 (0.85)	53 (0.51)
 FORMULA 60	NA	2356 (0.73)	NA
 FORMULA 61	NA	478 (0.72)	>2000

 FORMULA 62	NA	235 (0.92)	406 (0.43)
 FORMULA 63	930 (0.39)	9 (0.96)	45 (0.78)
 FORMULA 64	NA	137 (0.68)	617 (0.37)
 FORMULA 65	NA	30 (0.75)	238 (0.34)
 FORMULA 66	NA	523 (0.8)	853 (0.7)
 FORMULA 67	546 (0.31)	62 (1.06)	278 (0.66)
 FORMULA 68	NA	89 (0.92)	1422 (0.78)
 FORMULA 69	NA	243 (0.9)	2370 (0.51)
 FORMULA 70	NA	27 (1.20)	144 (0.74)
 FORMULA 71	NA	2053 (0.89)	NA

 FORMULA 72	NA	141 (1.08)	>2000
 FORMULA 73	62 (0.85)	2 (1.35)	23 (0.91)
 FORMULA 74	NA	49 (0.76)	322 (0.68)
 FORMULA 75	NA	70 (0.49)	NA
 FORMULA 76	NA	138 (1.01)	786 (0.66)
 FORMULA 77	NA	48 (0.60)	NA
 FORMULA 78	ND	ND	ND
 FORMULA 79	ND	ND	ND
 FORMULA 80	ND	ND	ND
 FORMULA 81	ND	ND	ND

 FORMULA 82	ND	ND	ND
 FORMULA 83	ND	ND	ND
 FORMULA 84	ND	ND	ND
 FORMULA 85	ND	ND	ND

5

EXAMPLES

10 Example 1: Synthesis of 1-(3-chloro-2-fluorobenzyl)-
3-(2-hydroxyethyl)-thiourea (Formula 2)

One molar equivalent of 3-chloro-2-fluoro-benzyl
 bromide (commercially available from e.g., Lancaster
 15 Synthesis, Ltd.) is permitted to react with 2 molar
 equivalents of potassium isothiocyanate in
 dimethylformamide (DMF) containing 0.5 molar
 equivalent of NaI at 90° C for 5 hours with stirring

to yield 3-chloro-2-fluorobenzyl isothiocyanate.

The reaction mixture is permitted to cool to room temperature, and the solution is diluted with H₂O and extracted with ether. The ether phase containing the product is removed and the reaction mixture extracted twice more with fresh ether. The ether phases are combined and the product is concentrated in a Speed Vac[®] vacuum centrifuge (using house vacuum) set in a water bath at about 45° C. When the ether has evaporated, the unpurified 3-chloro-2-fluorobenzyl isothiocyanate is a viscous liquid.

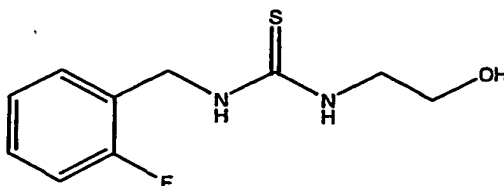
3.57 g of this compound is mixed with 3 molar equivalents of ethanolamine in acetonitrile, and a catalytic amount (less than 1%) of DMAP (N-N-dimethyl amino pyridine) is added. The reaction mixture is incubated for 14 hours at room temperature with constant stirring. The resulting solution is then concentrated using the Speed Vac[®] vacuum centrifuge in a 60° C-70° C water bath.

The product, 1-(3-chloro-2-fluorobenzyl)-3-(2-hydroxyethyl)-thiourea, is purified by liquid chromatography using 200-300 mesh silica gel in a glass column. The concentrated reaction solution is applied to the column and the column washed with three column volumes of Solvent A (50% ethyl acetate/50% hexanes). The product is then eluted using 2-3 column volumes of Solvent B (10% methanol/90% ethyl acetate). The eluted product is again concentrated in a Speed Vac[®] vacuum centrifuge to remove the solvent. The product is then permitted to stand at room temperature, where it crystallizes spontaneously. The crystals are stored in the freezer at -78°C.

The product has the following spectroscopic characteristics: ^1H NMR (D_6 DMSO, 300 MHz) δ 7.98 (br s, 1 H), 7.63 (br s, 1 H), 7.46 (t, $J=3.9$ Hz, 1 H), 7.32-7.18 (m, 2 H), 4.78 (br s, 1H), 4.72 (d, $J=3.9$ Hz, 2 H), 3.47 (br s, 4 H).

In order to compare the biological activity of 1-(3-chloro-2-fluorobenzyl)-3-(2-hydroxyethyl)-thiourea with that of the 2-fluorobenzyl derivative (FORMULA 4) and the 4-fluorobenzyl derivative (FORMULA 3), FORMULA 4 is synthesized using 2-fluoro-benzyl bromide (also commercially available) as the starting material. FORMULA 3 is synthesized using commercially purchased 4-fluorobenzyl isothiocyanate. Other synthetic steps are analogous to those used above to synthesize the compound of FORMULA 2.

The 2-fluorobenzyl isothioureia derivative (hereinafter termed FORMULA 4) has the following formula:



Formula 4

The physiological activity of these compounds was tested using four models: a rat locomotor model to assess sedation, an assay of cardiovascular activity in monkeys, a rat thermal paw withdrawal assay (Dirig et al., *J. Neurosci. Methods* 76:183-191 (1997) to test the alleviation of acute pain, and the

rat spinal nerve ligation allodynia model (Kim and Chung, *Pain* 50:355-363 (1992) to assess the alleviation of neuropathic pain and central sensitization typical of chronic pain. As is known to those of skill in the art, these tests are established pharmacological methods for determining sedation, cardiovascular effects, acute pain and chronic pain, respectively, of pharmaceutical agents.

10

Example 2: Sedative Activity

To test sedation, six male Sprague-Dawley rats were given up to 3 mg/kg of each compound in a saline or DMSO vehicle by intraperitoneal injection (i.p.). Sedation was graded 30 minutes following administration of the drug by monitoring locomotor skills as follows.

The Sprague-Dawley rats are weighed and 1 ml/kg body weight of an appropriate concentration (ie. 3 mg/ml for a final dose of 3 mg/kg) drug solution is injected intraperitoneally. FORMULA 3 is formulated in approximately 10% DMSO and FORMULA 2 and FORMULA 4 are formulated in 50% DMSO. The results are compared to 29 historical controls that were injected with 1 ml/kg saline or 50% DMSO. Rat activity is then determined 30 minutes after injection of the drug solution. Rats are placed in a dark covered chamber and a digicom analyzer (Omnitech Electronic) quantitates their exploratory behavior for a five-minute period. The machine records each time the rat interrupts an array of 32 photoelectric beams in the X and Y orientation.

The results show that, in comparison to the appropriate vehicle controls, none of the compounds caused a statistically significant reduction in the exploratory activity of the rats. FORMULA 2 and FORMULA 3 were tested at 1 mg/kg and FORMULA 4 was tested at 3 mg/kg. Thus, the compounds are not sedating.

10 Example 3: Effects on Cardiovascular System

To test the effect of the compounds on the cardiovascular system, six cynomolgus monkeys were given 500 µg/kg of each compound by intravenous injection (i.v.). The effects of each compound on the animals' blood pressure and heart rate was measured at time intervals from 30 minutes to six hours following administration of the drug. The peak change from a baseline measurement taken 30 minutes before drug administration is recorded using a blood pressure cuff modified for use on monkeys.

The monkeys are weighed (approximately 4 kg) and an appropriate volume (0.1 ml/kg) of a 5 mg/ml solution of each compound formulated in 10% DMSO is injected into the cephalic vein in the animals' arms. Cardiovascular measurements are made with a BP 100S automated sphygmomanometer (Nippon Colin, Japan) at 0.5, 1, 2, 4 and 6 hours.

The results show that, in comparison to the predrug control, none of the compounds have any detectable effect on the cardiovascular system.

Example 4: Alleviation of Acute Pain

Models to measure sensitivity to acute pain have typically involved the acute application of thermal stimuli; such a stimulus causes a programmed escape mechanism to remove the affected area from the stimulus. The proper stimulus is thought to involve the activation of high threshold thermoreceptors and C fiber dorsal root ganglion neurons that transmit the pain signal to the spinal cord.

The escape response may be "wired" to occur solely through spinal neurons, which receive the afferent input from the stimulated nerve receptors and cause the "escape" neuromuscular response, or may be processed supraspinally - that is, at the level of the brain. A commonly used method to measure nociceptive reflexes involves quantification of the withdrawal or licking of the rodent paw following thermal excitation. See Dirig, D.M. et al., *J. Neurosci. Methods* 76:183-191 (1997) and Hargreaves, K. et al., *Pain* 32:77-88 (1988), hereby incorporated by reference herein.

In a variation of this latter model, male Sprague-Dawley rats were tested by being placed on a commercially available thermal stimulus device constructed as described in Hargreaves et al. This device consists of a box containing a glass plate. The nociceptive stimulus is provided by a focused projection bulb that is movable, permitting the stimulus to be applied to the heel of one or both hindpaws of the test animal. A timer is actuated with the light source, and the response latency (defined as the time period between application of the stimulus and an abrupt withdrawal of the hindpaw)

is registered by use of a photodiode motion sensor array that turns off the timer and light. Stimulus strength can be controlled by current regulation to the light source. Heating is automatically terminated
5 after 20 seconds to prevent tissue damage.

Four test animals per group were weighed (approximately 0.3 kg) and injected intraperitoneally (i.p.) with 1 ml/kg of each compound formulated in approximately 50% dimethylsulfoxide (DMSO) vehicle.
10 Animals received a 0.3 mg/kg and a 3 mg/kg dose of the three compounds. Rats were acclimated to the test chamber for about 15 minutes prior to testing. The paw withdrawal latency was measured at 30, 60 and 120 minutes after drug administration. The right and
15 left paws were tested 1 minute apart, and the response latencies for each paw were averaged. Stimulus intensity was sufficient to provide a temperature of 45-50 degrees centigrade to each rat hindpaw.

20 The results show that none of the compounds provide analgesic effects in this bioassay of acute pain. The response latencies for rats treated with the compounds were not statistically different from the response latencies of the rats treated with
25 vehicle alone.

Example 5: Alleviation of Chronic Pain

A model for chronic pain (in particular
30 peripheral neuropathy such as causalgia) involves the surgical ligation of the L5 (and optionally the L6) spinal nerves on one side in experimental animals. Rats recovering from the surgery gain weight and display a level of general activity similar to that

of normal rats. However, these rats develop abnormalities of the foot, wherein the hindpaw is moderately everted and the toes are held together. More importantly, the hindpaw on the side affected by the surgery appears to become sensitive to pain from low-threshold mechanical stimuli, such as that producing a faint sensation of touch in a human, within about 1 week following surgery. This sensitivity to normally non-painful touch is called "tactile allodynia" and lasts for at least two months. The response includes lifting the affected hindpaw to escape from the stimulus, licking the paw and holding it in the air for many seconds. None of these responses is normally seen in the control group.

Rats are anesthetized before surgery. The surgical site is shaved and prepared either with betadine or Novacaine. Incision is made from the thoracic vertebra Xl11 down toward the sacrum. Muscle tissue is separated from the spinal vertebra (left side) at the L4 - S2 levels. The L6 vertebra is located and the transverse process is carefully removed with a small rongeur to expose the L4 - L6 spinal nerves. The L5 and L6 spinal nerves are isolated and tightly ligated with 6-0 silk thread. The same procedure is done on the right side as a control, except no ligation of the spinal nerves is performed.

A complete hemostasis is confirmed, then the wounds are sutured. A small amount of antibiotic ointment is applied to the incised area, and the rat is transferred to the recovery plastic cage under a regulated heat-temperature lamp. On the day of the experiment, at least seven days after the surgery,

six rats per test group are administered the test drugs by intraperitoneal (i.p.) injection or oral gavage. For i.p. injection, the compounds are formulated in approximately 50% DMSO and given in a volume of 1 ml/kg body weight. FORMULA 2 was tested at doses ranging between 1 and 300 μ g /kg, FORMULA 3 was tested at doses between 0.1 and 3 mg/kg and FORMULA 4 was tested at doses of 0.3 and 3 mg/kg. FORMULA 2 was also administered by oral gavage at doses of 0.1, 0.3 and 1 mg/kg body weight to 24-hour fasted rats. A volume equal to 1 ml/kg body weight of an appropriate concentration (ie. 1 mg/ml for a 1 mg/kg dose) of FORMULA 2 formulated in approximately 50% DMSO was injected using an 18-gauge, 3-inch gavage needle that is slowly inserted through the esophagus into the stomach.

Tactile allodynia is measured prior to and 30 minutes after drug administration using von Frey hairs that are a series of fine hairs with incremental differences in stiffness. Rats are placed in a plastic cage with a wire mesh bottom and allowed to acclimate for approximately 30 minutes. The von Frey hairs are applied perpendicularly through the mesh to the mid-plantar region of the rats' hindpaw with sufficient force to cause slight buckling and held for 6-8 seconds. The applied force has been calculated to range from 0.41 to 15.1 grams. If the paw is sharply withdrawn, it is considered a positive response. A normal animal will not respond to stimuli in this range, but a surgically ligated paw will be withdrawn in response to a 1-2 gram hair. The 50% paw withdrawal threshold is determined using the method of Dixon, W.J., *Ann. Rev. Pharmacol.*

Toxicol. 20:441-462 (1980). The post-drug threshold is compared to the pre-drug threshold and the percent reversal of tactile sensitivity is calculated based on a normal threshold of 15.1 grams.

5 The results showed that FORMULA 4 had no analgesic activity at doses up to 3 mg/kg. Surprisingly, AGN 196204 and FORMULA 2 were both able to reduce the response to the tactile stimuli that indicate tactile allodynia. FORMULA 3 reversed the allodynic pain by
10 34% at an i.p. dose of 0.3 mg/kg, 32% at 1 mg/kg and 26% at 3 mg/kg. FORMULA 2 reversed the allodynia by 55% at an i.p. dose of 3 µg/kg, 85% at 10 µg/kg, 90% at 30 µg/kg, 95% at 100 µg/kg and 92% at 300 µg/kg. The oral doses of FORMULA 2 ranging from 0.1 to 1
15 mg/kg alleviated the allodynic pain by 82-86%. Thus, FORMULA 3 and FORMULA 2 are analgesic in a model of chronic pain.

20 Example 6: Treatment of Allodynia with FORMULA 3

25 A 50 year old male in generally good physical condition suffers from serious pain to his upper body due caused by contact of his skin with his clothing. The patient is unable to wear clothing on his upper body without severe pain. His symptoms suggest a diagnosis of shingles.

30 The patient is given a therapeutically effective oral dose of FORMULA 3 in capsule form as needed for the treatment of pain. Following two day's treatment, the patient reports that the allodynia resulting from shingles is markedly reduced, and that he is able to
35 wear clothing on his upper body with greater comfort.

Example 6: Treatment of Allodynia with FORMULA 2

5 Same facts as in Example 5, except the patient
is given a therapeutically effective oral dose of
FORMULA 2 in capsule form as needed for the treatment
of pain. Following two day's treatment, the patient
reports that the allodynia resulting from shingles is
markedly reduced, and that he is able to wear
10 clothing on his upper body with greater comfort.

Example 7: Treatment of Visceral Pain with FORMULA 3

15 A 43 year old female patient suffering from
colon cancer and undergoing chemotherapy experiences
severe visceral pain associated with this primary
condition. Treatment of this pain with opiates have
been ineffective to provide substantial relief.

20 The patient is given a therapeutic amount of
FORMULA 3 by intravenous infusion in a
pharmaceutically acceptable vehicle. The treatment
is given twice daily. After two days the patient
reports a significant alleviation in the visceral
25 pain associated with her condition.

Example 8: Treatment of Visceral Pain with FORMULA 2

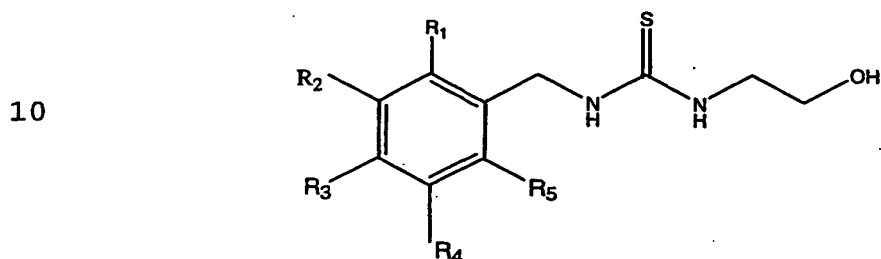
5 Under the same facts as Example 7, except the
patient is given FORMULA 2 instead of FORMULA 3.
After two days the patient reports a significant
alleviation in the visceral pain associated with her
condition.

10 The examples contained herein are intended to be
exemplary only, and do not limit the scope of the
invention, which is defined by the claims that
conclude this specification.

CLAIMS

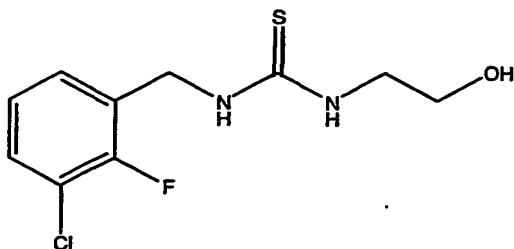
We claim:

- 5 1. A composition comprising a compound represented by the formula:



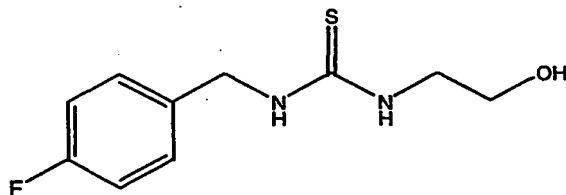
- 15 wherein R_1 and R_5 are independently selected from the group consisting of Cl, F, I, Br, C_{1-3} alkyl, C_{1-3} alkoxy, trifluoromethyl, hydroxyl or H, R_2 and R_4 are independently selected from the group consisting of Cl, F, I, Br, C_{1-3} alkyl, C_{1-3} alkoxy, hydroxyl, trifluoromethyl or H, and R_3 is selected from the
- 20 group consisting of F or H; and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds,
- and a pharmaceutically acceptable excipient.

- 25 2. The composition of claim 1 wherein the compound is not represented by the formula:



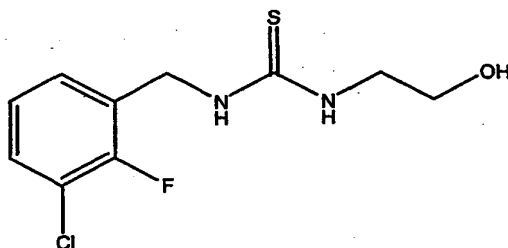
and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

3. The composition of claim 1 wherein the compound is not represented by the formula:



5 and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

4. The composition of claim 3 wherein the compound is not represented by the formula



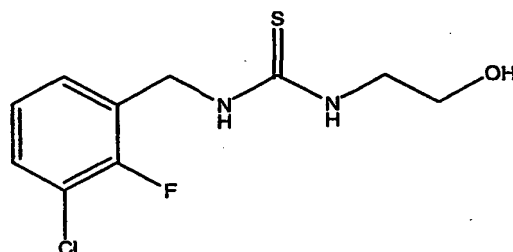
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and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

5. The composition of claim 1 wherein said composition comprises a pharmaceutically acceptable excipient for therapeutic delivery of said compound.

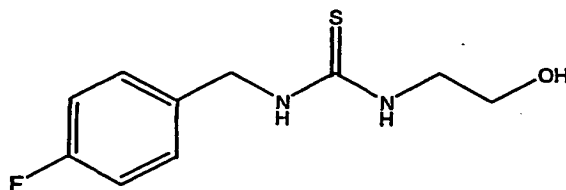
6. The composition of claim 5 wherein said compound is not represented by the formula:

20



and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

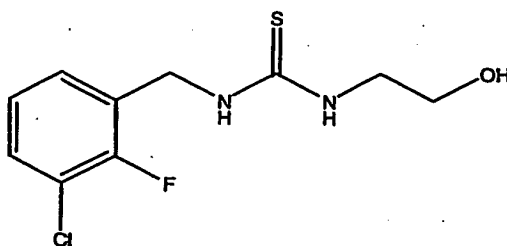
7. The composition of claim 5 wherein said compound
5 is not represented by the formula:



and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

10

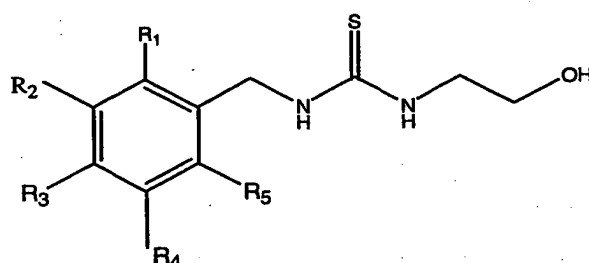
8. The composition of claim 7 wherein the compound is not represented by



15

and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

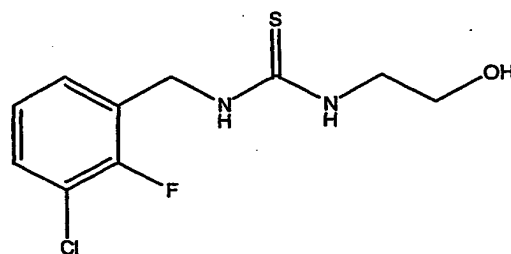
9. A method of treating pain in a mammal in need thereof comprising the step: administering to said patient a therapeutically effective dose of a composition comprising a compound represented by having the formula:



10

- wherein R₁ and R₅ are independently selected from the group consisting of Cl, F, I, Br, C₁₋₃ alkyl, C₁₋₃ alkoxy, trifluoromethyl, hydroxyl or H, R₂ and R₄ are independently selected from the group consisting of Cl, F, I, Br, C₁₋₃ alkyl, C₁₋₃ alkoxy, hydroxyl, trifluoromethyl or H, and R₃ is selected from the group consisting of F or H; and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

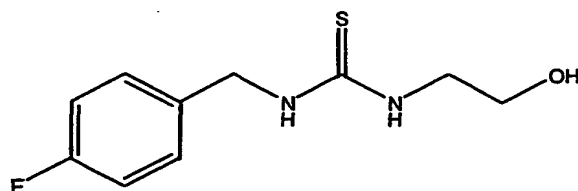
10. The method of claim 9 wherein said compound is not represented by the formula



and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

11. The method of claim 10 wherein said compound is administered orally.

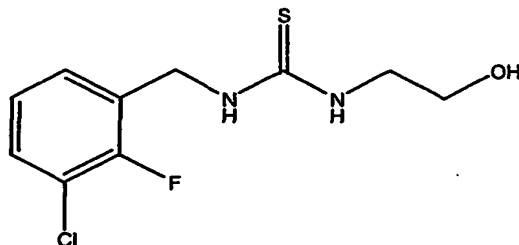
12. The method of claim 9 wherein said compound is not represented by the formula



and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

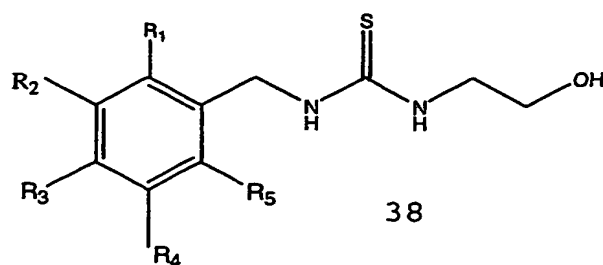
13. The method of claim 9 wherein said compound is administered orally.

14. The method of claim 12 wherein said compound is not represented by the formula



and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

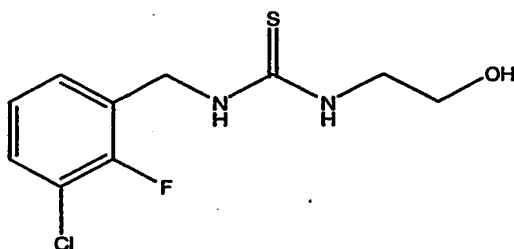
15. A compound represented by the formula:



wherein R_1 , R_2 , R_3 , R_4 and R_5 are each independently
5 selected from the group consisting of Cl, F, Br or H
with the proviso that at least one of R_2 and R_4 are
Cl, F, or Br and that at least three of R_1 , R_2 , R_3 , R_4 ,
and R_5 are H; and alkyl esters thereof, and
pharmaceutically acceptable salts of these compounds.

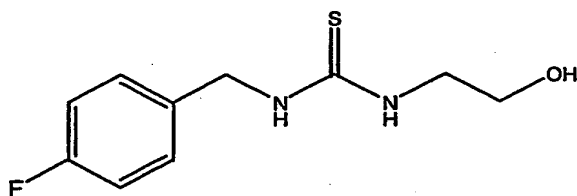
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16. A compound of claim 15 not represented by the
formula



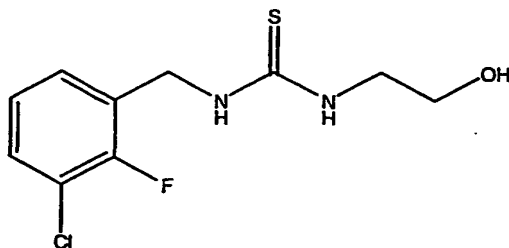
and alkyl esters thereof, and pharmaceutically
15 acceptable salts of these compounds.

17. A compound of claim 15 not represented by the
formula



20 and alkyl esters thereof, and pharmaceutically
acceptable salts of these compounds.

18. A compound of claim 17 not represented by the
formula



and alkyl esters thereof, and pharmaceutically acceptable salts of these compounds.

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(57) Abstract: Methods and compositions for the treatment of pain. Particularly disclosed are new compositions for the treatment of chronic pain, and methods for their use.

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A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal, BIOSIS, EMBASE, CHEM ABS Data, PHARMAPROJECTS

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Y	GB 2 206 347 A (SANDOZ PRODUCTS LTD) 5 January 1989 (1989-01-05) *cf. abstract, page 7, 2nd and 3rd paras.* ---	1-18
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☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

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